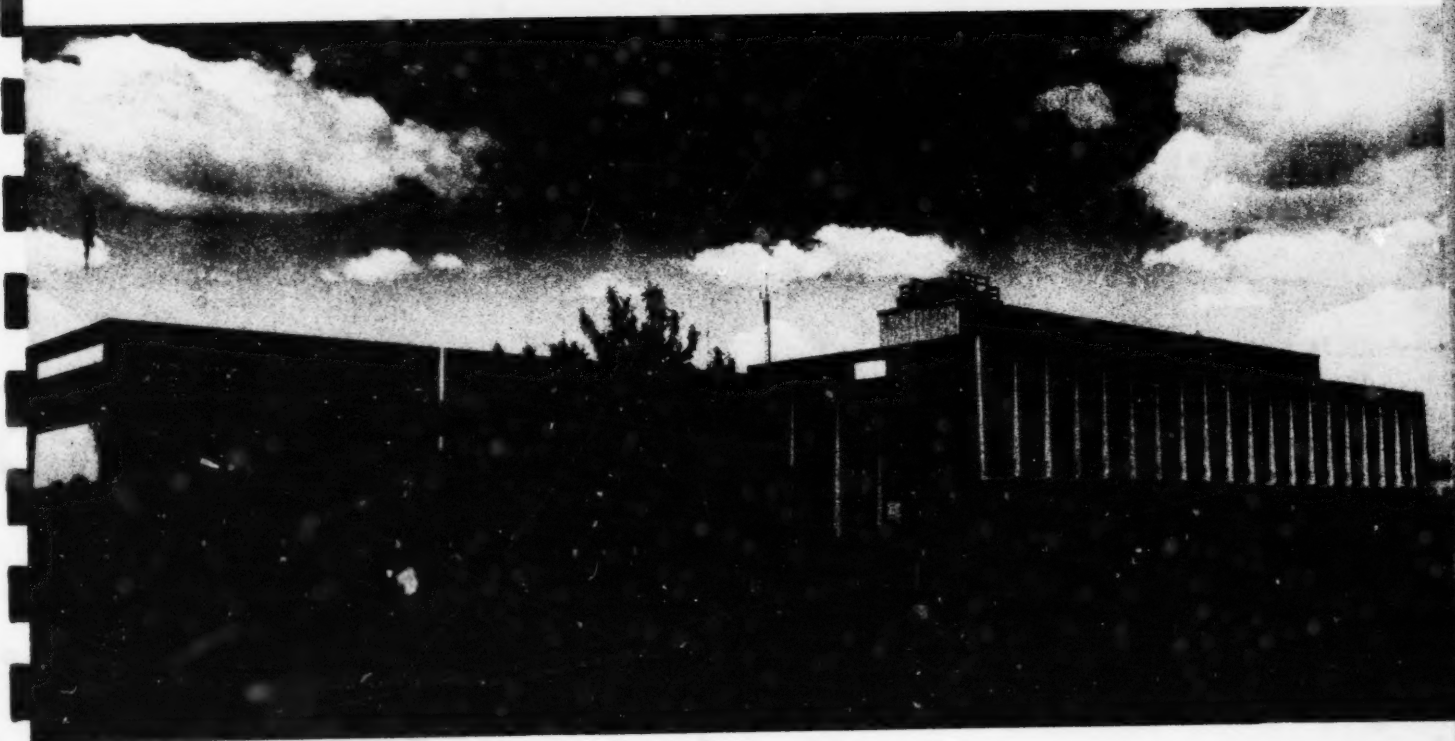




**ontario hydro
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**EFFECTIVENESS OF FILTERED MERCURY
VAPOUR LIGHTS IN SEQUENCE TO
LEAD FISH IN A FOREBAY SITUATION**

Report No 83-250-K

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Unit Head -
Field Oriented Research
Biological Research Section
Chemical Research Department

ABSTRACT

Mercury vapour light has been identified as an effective fish attractant. This study was conducted to determine whether fish could be led using a series of mercury vapour lights for possible application as a fish concentrator for eventual removal from a forebay. The results of this study conducted in the Nanticoke GS forebay suggest that fish can be led by either a series of lights which are sequentially turned on and off, or a series of lights which, initially on, are sequentially turned off. Although movement in an upstream direction was apparent, the system appeared to be more effective in a downstream direction suggesting that application would be most effective with a fish extractor which generates a current such as a modified fish pump. The system was not effective in a high current situation (37 cm/s) such as when the Nanticoke tempering pumps were operating.

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To Mr. F.J. Kee
Director of Research

EFFECTIVENESS OF MERCURY VAPOUR LIGHTS IN
SEQUENCE TO LEAD FISH IN A FOREBAY SITUATION

Laboratory and field studies have demonstrated that filtered mercury vapour lights are effective fish attractants (Ontario Hydro Research Division Report No's 80-413-K and 82-165-K). In a forebay situation these lights can effectively concentrate fish in the area of an extractor and consequently reduce fish losses due to impingement.

Although the range over which a mercury vapour light can effectively attract fish is not known, results of a study conducted at Nanticoke suggest that the effective distance of the lights varies with water clarity and ambient light and probably does not generally exceed 20 m (Ontario Hydro Research Division Report No 82-165-K). As most generating station forebays are substantially larger than 20 m in length, mercury vapour lights situated at an extractor in a forebay would probably not effectively attract all fish in that forebay. Thus, to increase the effectiveness of the extractor a system which could attract fish from outside the range of a light situated at the extractor would be required.

Consequently studies were carried out in the Nanticoke forebay (Figure 1) to test the effectiveness of a series of three mercury vapour lights in leading fish.

MATERIALS AND METHODS

Lighting

Lighting used throughout the experiments consisted of clear 175 W mercury vapour lamps enclosed in waterproof housings. The housings are fully described in Ontario Hydro Research Division Report No 82-165-K, and are shown in Figure 2(a). Briefly, each housing consisted of a 40.6 cm (16") length of 1.9 cm (0.75") wall 40.6 cm (16") diameter PVC pipe, a circular plate of 1.9 cm (0.75") PVC which was inset and welded into the bottom and a

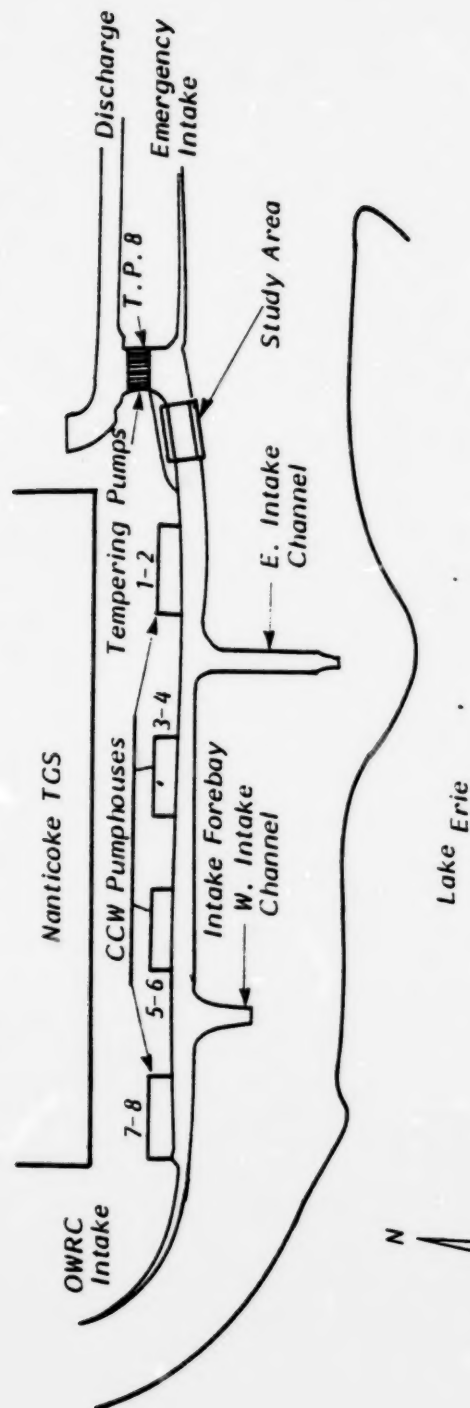
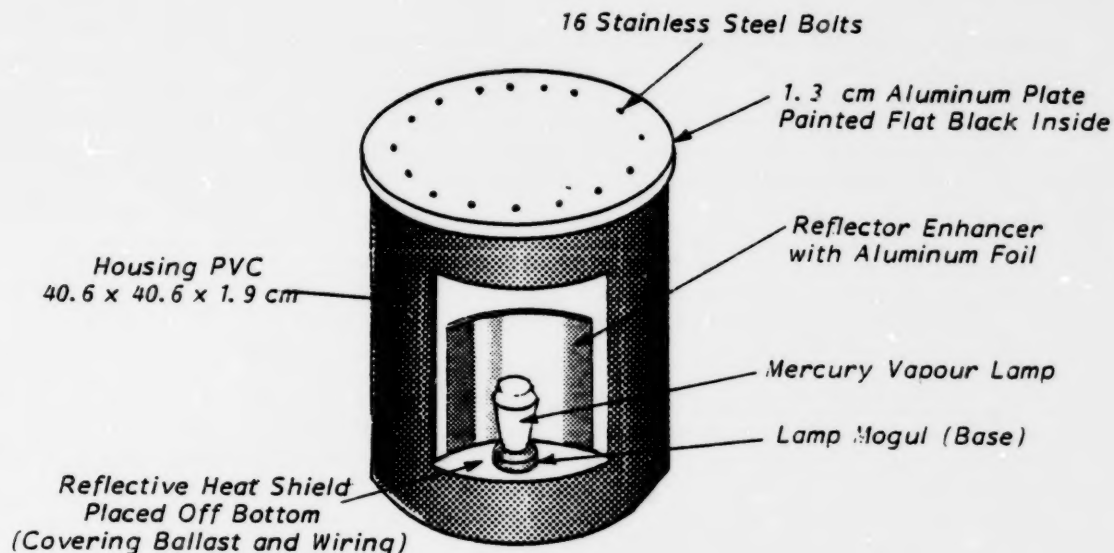
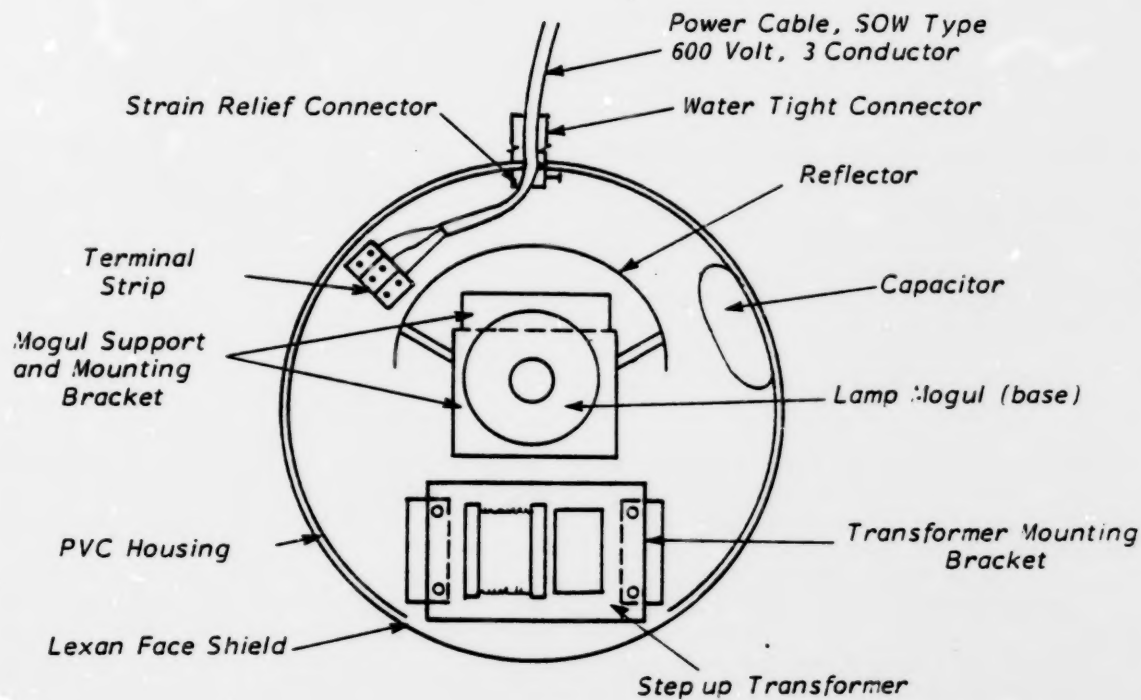


FIGURE 1
INTAKE AREA SITE PLAN WITH LOCATION
OF SEQUENTIAL LIGHT STUDY AREA



(a)



(b)

FIGURE 2
MERCURY VAPOUR LIGHT AND HOUSING
(a) EXTERNAL VIEW, (b) INTERNAL COMPONENTS

drilled and grooved upper flange to accommodate an O-ring and seal the 1.3 cm (0.5") aluminum top plate. The faceplate or window consisted of molded Lexan-CO₂ welded into the side of the housing. One layer of Moonblue Geletram filter material was placed over the faceplate in order to reduce transmitted light in the yellow and orange and highlight the blue-green regions of the spectrum.

A number of changes were made to the wiring of the housings in response to concerns by Nanticoke TGS electrical personnel over the safety of the previous electrical arrangement. These changes included:

1. Installation of a ballast kit (transformer and capacitor) into the underwater housing. This ensured that all connecting power cables external to the housings carried a maximum load of 120 V, 15 A, which could then be ground fault protected. It also isolated all high voltage (up to 600 V) power lines within the housing where leakage could not adversely affect personnel.
2. Replacement of power cable from light control box to housings with 50 W type (underwater rated) cable. The previous cable was initially authorized on the basis of short term, one time usage only.

An overview of the placement of the ballast kit within the housing is shown in Figure 2(b).

Electrical power supply for the experimental apparatus was obtained from a 600 V outlet in the Nanticoke TGS pumphouse, which was then stepped down via a "power sender" to provide four 120 V, 15 A, ground fault protected outlets. Three of the outlets supplied power to the acoustic equipment and heaters, while the fourth supplied the light control box. Within the light control box, a master cutoff switch fed three fused single throw switches which allowed each light to be individually controlled. Details of power supply to the lights are shown diagrammatically in Figure 3.

Specialized light platforms were constructed in order to suspend the lights within the experimental area (Figure 4). The base of each platform consisted of two 6.1 m (20 ft) sections of 15.2 cm (6") steel pipe interconnected with 3.8 cm (1.5") pipe. A piece of 1.2 m x 2.4 m x 1.9 cm (4 ft x 8 ft x 3/4") plywood was attached at each end to serve as a platform for counter-weights on one end and a working platform on the other. A railing, constructed of 3.8 cm (1.5") steel pipe served as a safety barrier while working on the platform as well as a point of attachment for the pivoting sleeves through which the support pipes

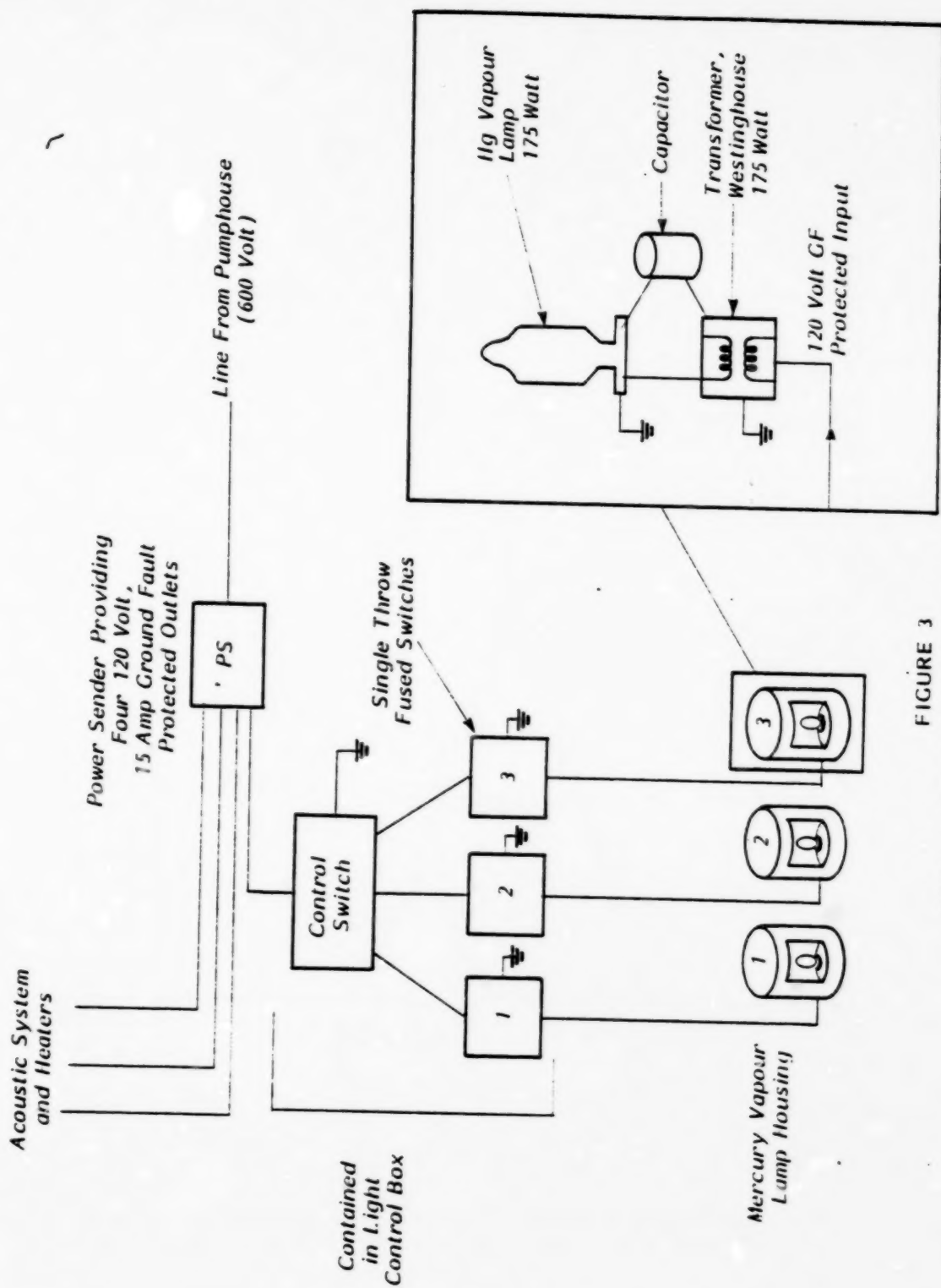


FIGURE 3
DETAILS OF POWER SUPPLY TO MERCURY
VAPOUR LAMPS AND ACOUSTIC EQUIPMENT

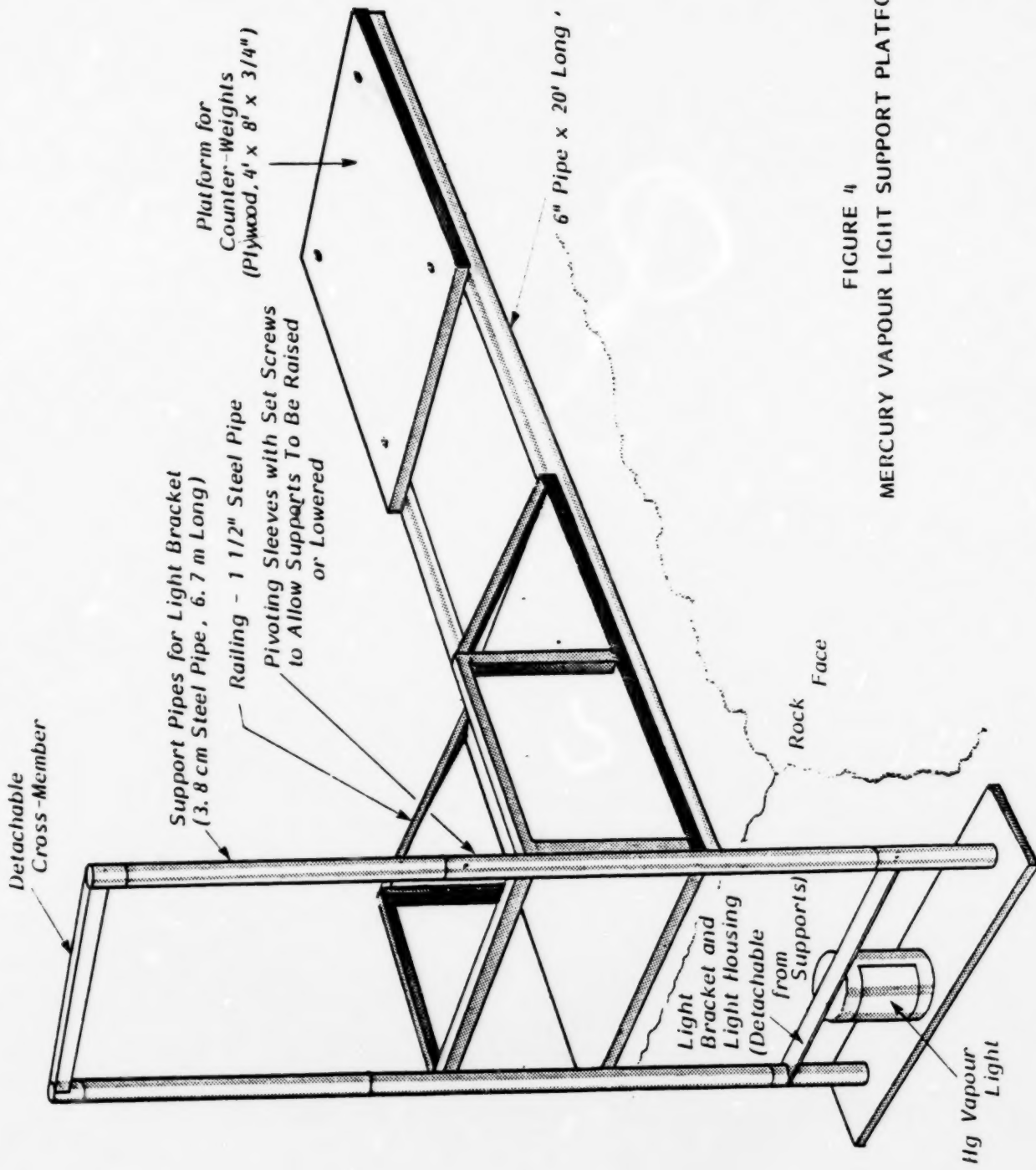


FIGURE 4
MERCURY VAPOUR LIGHT SUPPORT PLATFORM

for the light bracket travelled. Set screws on the sleeves allowed the light to be held at any position along the support pipes. The support pipes allowed for a maximum depth setting of approximately 6 m. In field trials with the light positioned at the 5 m depth, it was found that only a slight positive buoyancy was exhibited by the light, allowing it to be submerged from a rear horizontal position (floating on the surface) by maintaining a steady upward pressure on the top cross member. When vertical it was tied into position to prevent it from slowly rising to the surface of its own accord.

Assessment of Attraction

An acoustic fish censusing system (see Ontario Hydro Research Division Report Nos C78-157-K, C79-87-K for a description) was employed to assess the extent of fish attraction to the lights. The transducer was positioned upstream of the lights at a depth of approximately 3.0 m with the beam directed horizontally across the front of the lights (Figure 5). The receiving and processing components of the acoustic system were maintained in a heated van.

Experimental Design

The first set of experiments consisted of observations of fish behaviour at one light over a time period of 90 min, with the light off for 15 min, on for 60 min and off for an additional 15 min. Three replicates of this test were conducted at each light. Light intensity measurements were also obtained during this time.

The second set of experiments consisted of observations of fish behaviour at two lights when the lights were sequentially turned on and off with a 3 min on-time overlap. A typical 60 min trial consisted of 10 min off, 23 min with the 1st light on, 20 min with the second light on and 10 min off. Experiments were conducted with and against the current at light spacings of 8 and 11 m.

The final set of experiments consisted of observations of fish behaviour at 3 lights when the lights were operated in two different manners. In the first case, lights were turned on and off sequentially with a 5-min on-time overlap. A typical 80 min trial consisted of 10 min off, 25 min with the first light on, 25 min with the second light on, 20 min with the third light on, and 10 min off. In the second case, following a 10 min control period with lights off, all lights were turned on simultaneously and then sequentially turned off at 20 min intervals, followed by 10 min with all lights off. These experiments were conducted before and after tempering pumps were restarted on Dec 3/82. In

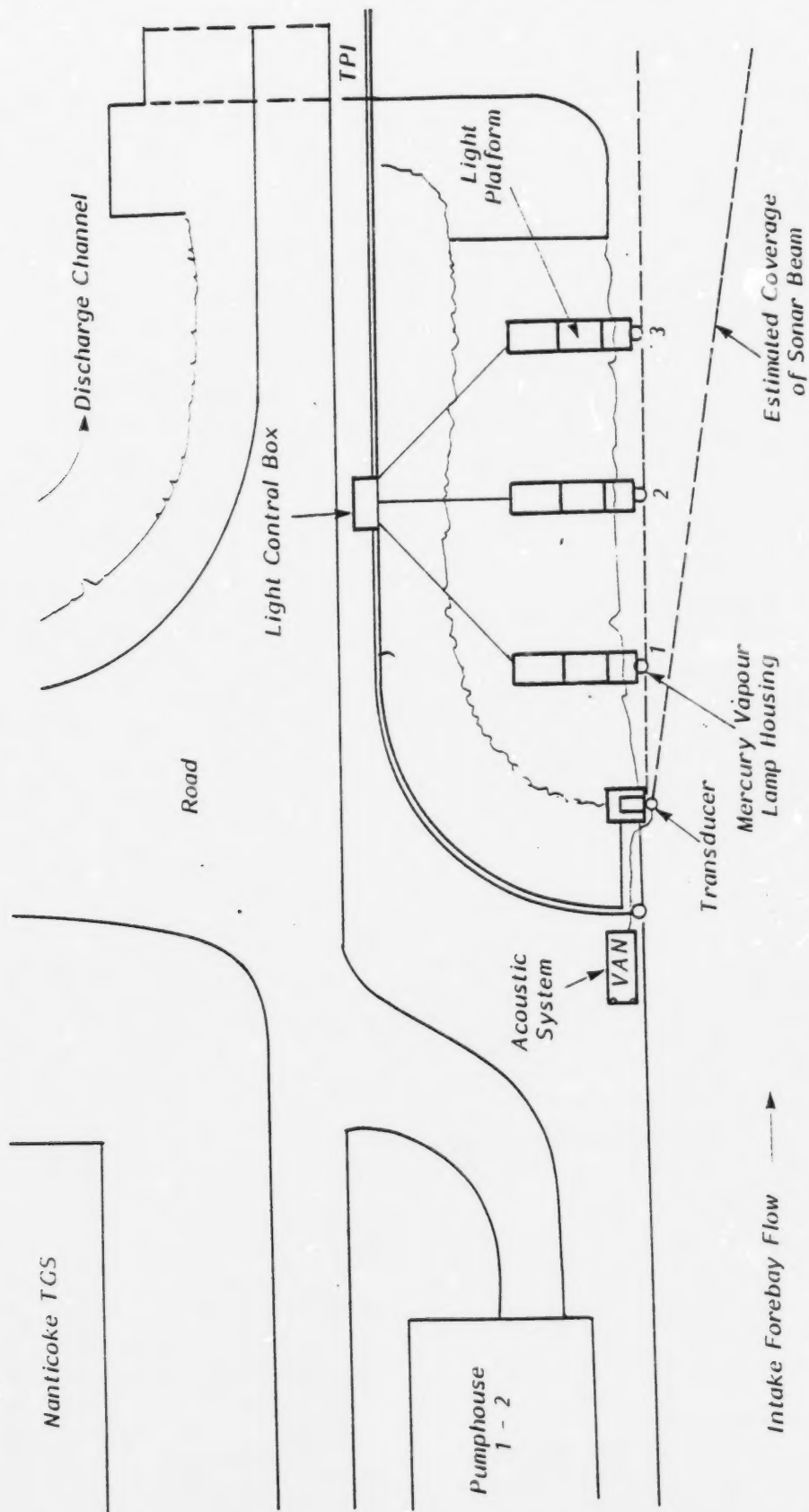


FIGURE 5
 DIAGRAM OF EXPERIMENT SET-UP SHOWING MERCURY
 VAPOUR LIGHTS AND ACOUSTIC EQUIPMENT

both cases as well, experiments were conducted with and against the current with a spacing of 8 m between the lights. A summary of the number of trials of each test type is presented in Table I and a description of all tests run is in Appendix 1.

Additionally, water temperature and turbidity measurements were obtained daily throughout the experimental period.

TABLE I

SUMMARY OF EXPERIMENTAL TESTS CONDUCTED
WITH TWO AND THREE LIGHTS

TWO LIGHTS

Light Spacing (m)	On-time Overlap (min)	No of Trials for Each Experimental Light Sequence			
		1-2*	2-3	3-2	2-1
11	3	3	3	3	3
8	3	1	1	1	1

THREE LIGHTS

Light Spacing (m)	On-time Overlap (min)	Tempering Pumps	No of Trials for Each Experimental Light Sequence			
			1-2-3	3-2-1	123-23-3	123-12-1
8	5	Off On	2 1	4 0		
	20	Off On			4 2	4 1

* Read as No 1 light followed by No 2 light

Analysis of Sonar Output

Throughout the course of these experiments, attempts were made to adjust the depth ranges of the sonar system so that fish associated with a particular light were exclusively counted in one depth range. Unfortunately, this could not be accomplished. Consequently, when presenting data from the digital output of the sonar, correction factors, where necessary, had to be incorporated to account for fish in a particular depth zone that were associated with the light in the adjacent depth zone.

RESULTS AND DISCUSSION

Experimental Conditions

When tempering pump (TP) No 8 alone was operating, currents in the test area of the forebay were approximately 6.5 cm/s but averaged approximately 37 cm/s when all tempering pumps were operating. Water temperatures during these trials ranged from 7 to 12°C while turbidity ranged from 4.3 to 13.5 NTU.

The light intensities generated by one filtered mercury vapour light on November 17 at 2000 h and 5.6 NTU turbidity are listed in Appendix 1. Light intensities dissipated rapidly from 1220 lux at 0.5 m to 0.1 lux at 6.5 m. Intensities to either side of the light were 2 to 3 lux at 0.5 m.

Based on limited dip netting and visual observations the fish in the forebay were primarily smelt (Osmerus mordax) and emerald shiners (Notropis atherinoides). Juvenile gizzard shad (Dorosoma cepedianum) which were very abundant in the Nanticoke forebay during November and December 1981 (Ontario Hydro Research Division Report No 82-165-K) were not observed.

Attraction to a Single Light

In the first set of experiments it was determined that each light when turned on would in fact attract fish. A typical visicorder output is in Figure 6(a). As can be seen in the figure, when No 2 light was on, a band of echoes (A) at the location of the light was apparent. This compares with a no light situation in which few if any fish were apparent in the sonar output (Figure 6b).

Accumulation of fish in front of a single light was immediate, reaching a plateau within 5 min of the light being turned on (Figure 7). Although the number of echoes per transmission was rather variable there appeared to be no increase with time in

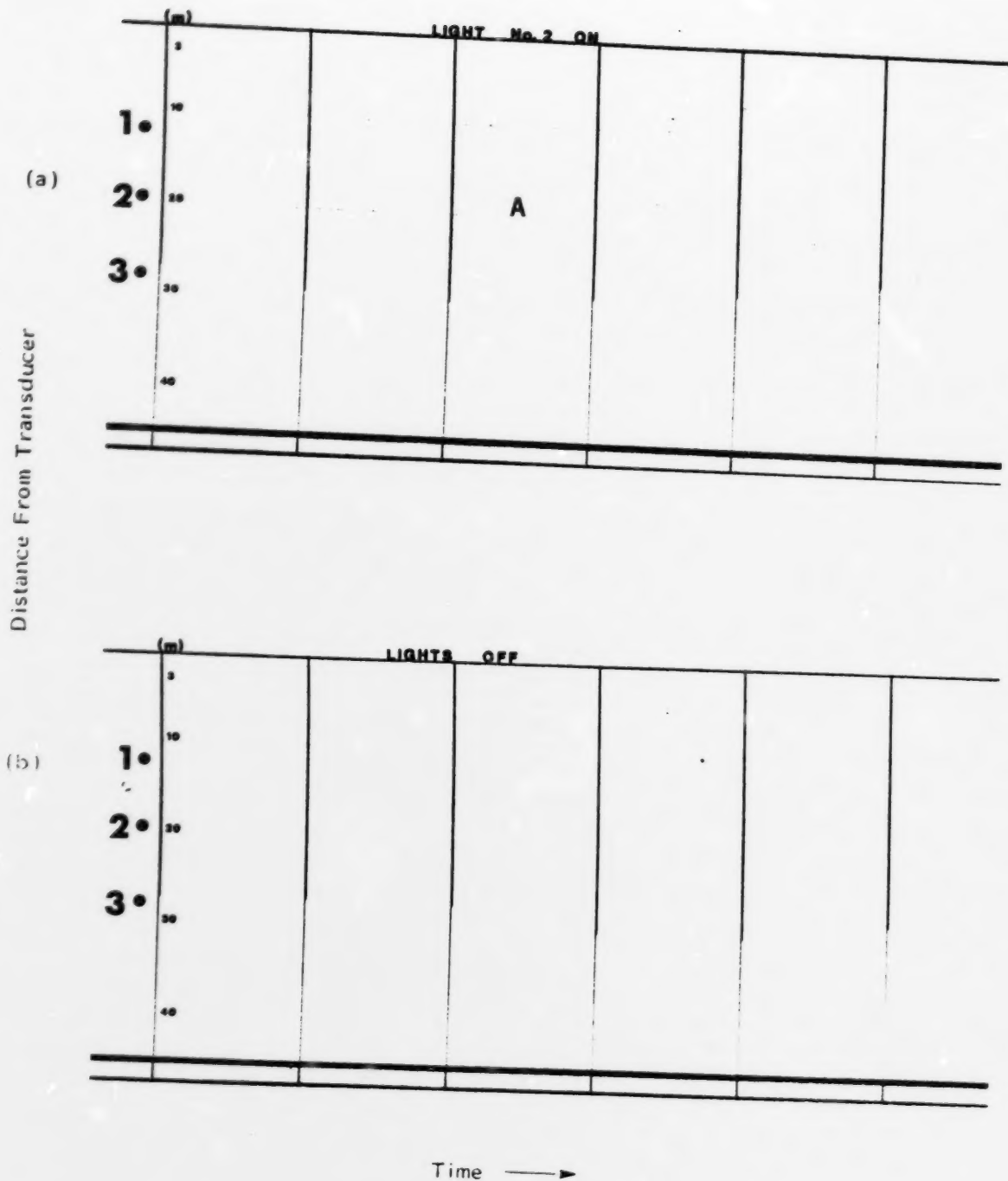


FIGURE 6

PORTION OF SONAR OUTPUT FOR (a) NO 2 LIGHT ON AND (b) NO LIGHTS ON. A - NOTE BAR OF ECHOES ASSOCIATED WITH LIGHT NO 2. ● - POSITION OF LIGHTS

the number of echoes. This indicates a relatively constant number of fish within the beam of the sonar but is only suggestive of a constant number of fish in front of the light as the number of fish outside the beam could in fact be increasing or decreasing. When the light was turned off, the number of echoes immediately dropped to the original levels and remained there.

Lights Turned On and Off in Sequence

In one set of experiments one light was turned on for approximately 20 min, followed by a second light for 23 to 25 min, followed by a third light for 23 to 25 min. There was a 3 to 5 min overlap when two lights were turned on. This procedure was followed for the sequence of light 1, light 2, light 3 (with the current) and light 3, light 2, light 1 (against the current). Similar tests were run with two lights only; however, results of these tests were not different from those of three lights and consequently will not be reported separately. In addition, results were similar for tests run with light spacings of 8 and 11 m and will not be reported separately.

A digital output (ie, number of echoes) for the sequence of lights, 3-2-1-2-3, is displayed in graphic form in Figure 8. Although this particular output is for lights turned on and off in sequence in an upstream direction (light 3-2-1) followed immediately by that of lights turned on and off in a downstream direction (light 1-2-3), the results are similar to tests run in a downstream and upstream direction separately. As with a single light the number of echoes at the No 3 light increased rapidly after it was turned on. When No 2 light was turned on, the number of echoes associated with the No 2 light increased gradually over the 5 min period when No 2 and No 3 lights were on simultaneously until No 3 light was turned off. At this point the echoes at light No 3 declined sharply and those at light No 2 increased more rapidly. A similar situation was apparent for each other combination of lights. When the final light (No 3) was turned off the number of echoes dropped quickly to base line levels at that light.

On the visicorder output some fish could be tracked from an upstream light to a downstream light (noted as diagonal lines on the sonar output) when the latter was turned on and the former was turned off. As an example of this observation, Figure 9(a) illustrates the sonar output obtained when No 1 light is turned off and No 3 light is turned on. In the figure No 3 light was turned on just prior to the point where this photograph was taken. Note the high density of echoes at light No 1 (upper) prior to it being turned off (A) and the rapid reduction in the density of echoes after it was turned off (B). Note also the lower density of echoes at light No 3 (C) increasing immediately when No 1 light was turned on (D) and the continuous diagonal lines from light No 1 to light No 3 near the point where the No 1 light was turned off (E).

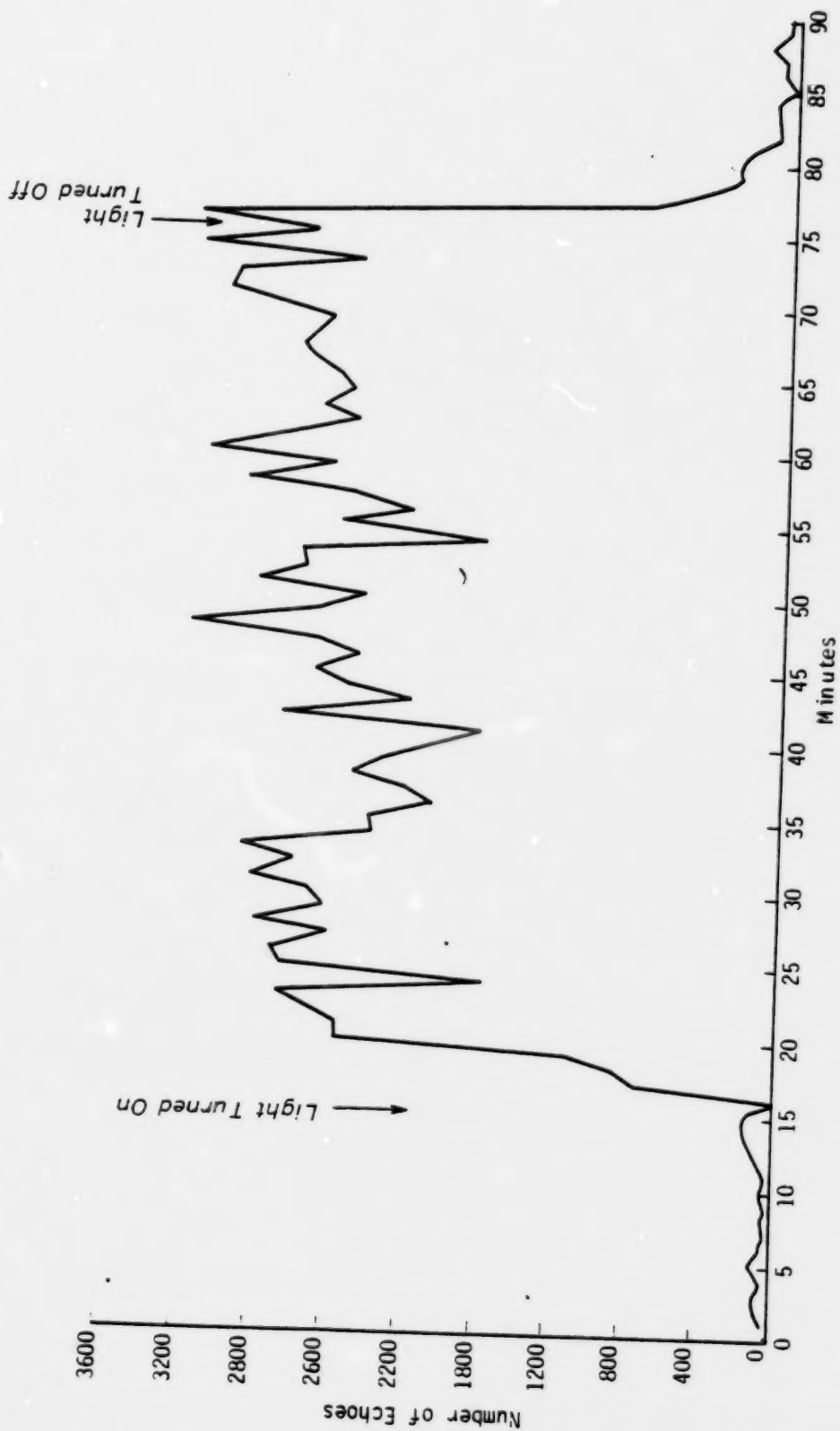


FIGURE 7
NUMBER OF ECHOES ASSOCIATED WITH A SINGLE MERCURY VAPOUR
LIGHT (NO 2), RECORDED ON THE DIGITAL OUTPUT OF THE SONAR

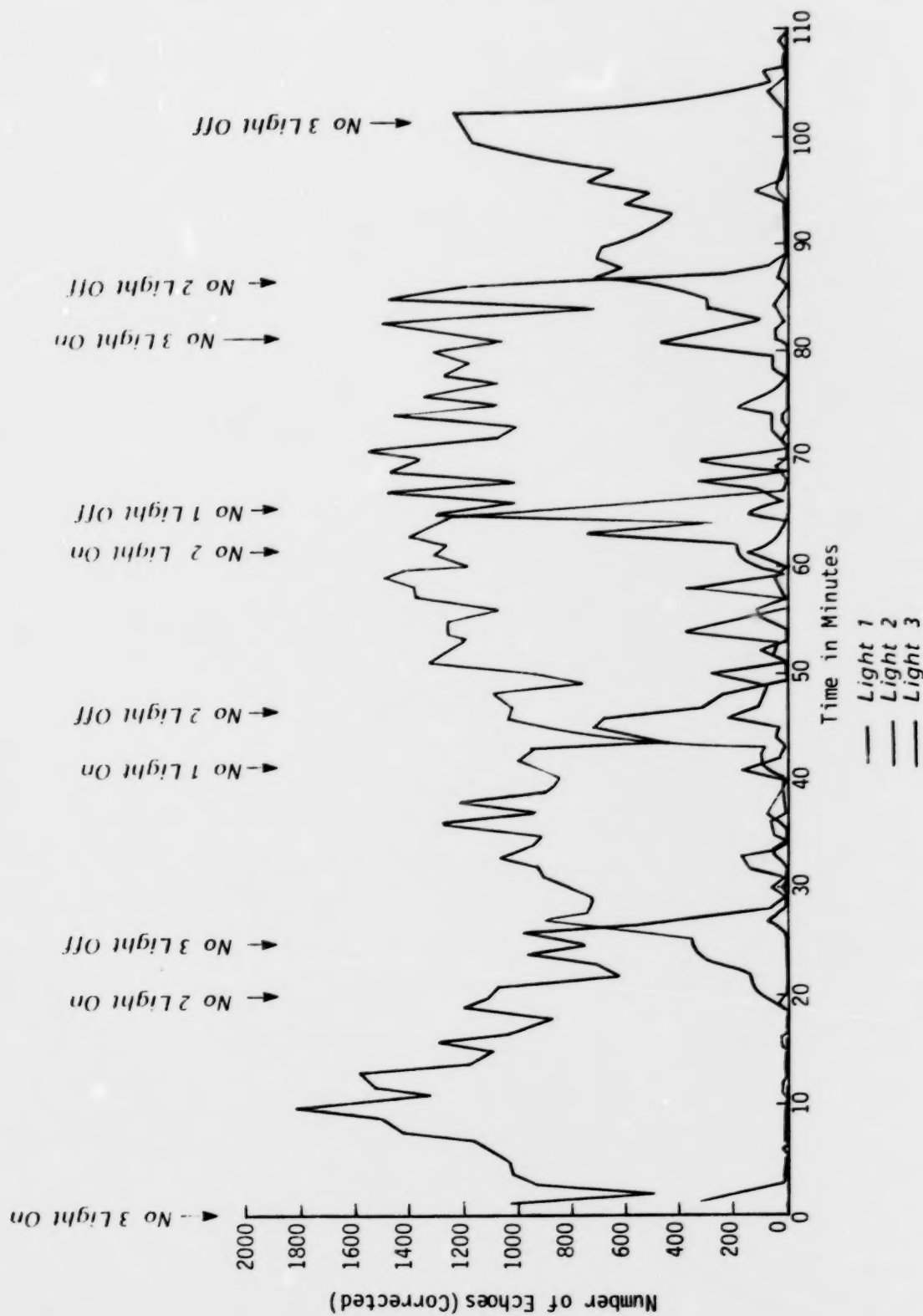


FIGURE 8
NUMBER OF ECHOES ASSOCIATED WITH LIGHTS NO 1-3 WHEN
THE LIGHTS WERE TURNED ON AND OFF IN SEQUENCE

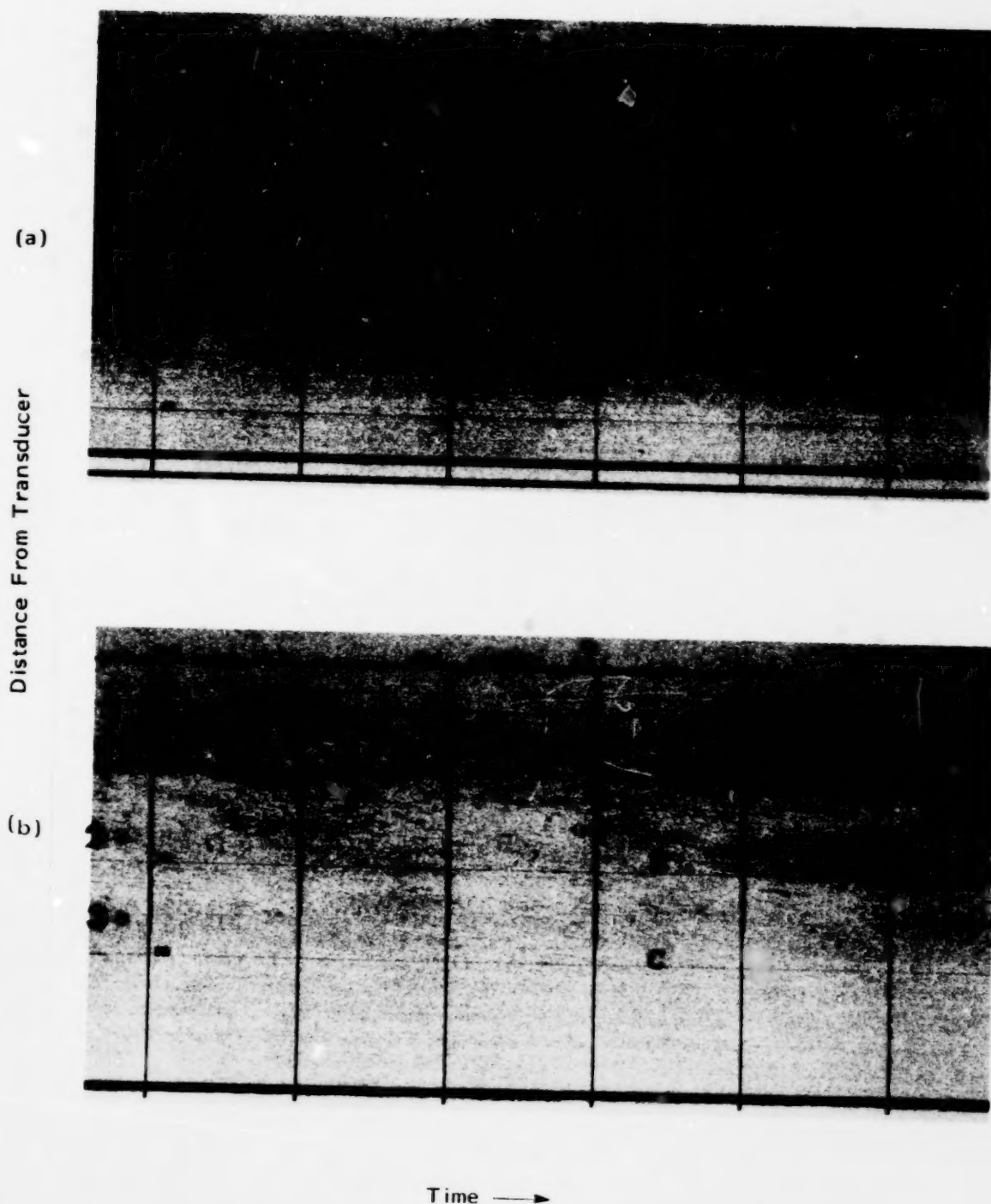


FIGURE 9

PORTION OF SONAR OUTPUT FOR (a) NO 3 LIGHT TURNED ON,
 NO 1 LIGHT TURNED OFF, (A-E SEE TEXT) AND (b) ALL LIGHTS
 ON (A-C SEE TEXT) ● - POSITION OF LIGHTS

Results observed when lights were turned on and off, sequentially, in an upstream direction were similar to those observed in a downstream direction with one notable exception. Although echoes at the upstream light (No 1, for example) increased immediately after the downstream light was turned off (No 2 light), there were no obvious diagonal lines on the sonar output in an upstream direction, but there were, in fact, some diagonal lines in a downstream direction from light No 2. The absence of diagonal lines in an upstream direction may be related to the size of the sonar beam, such that the likelihood of observing a fish moving upstream (the direction of decreasing cone size) is less than that of observing a fish moving downstream (the direction of increasing cone size). An alternative hypothesis is that when a light is turned off and the light intensity diminishes, the fish swim in closer to the light, which is outside of the sonar beam, before proceeding to the upstream light. The presence of diagonal lines in a downstream direction suggests some downstream loss of fish when the light is turned off, possibly due to disorientation of some fish as a result of the sudden reduction in light intensity.

Lights Turned Off in Sequence

In this set of experiments all three lights were turned on followed by sequentially turning off individual lights (in an upstream or downstream direction) at 20 min intervals.

When all lights were turned on fish immediately accumulated in front of the lights forming three bars of echoes (A, B and C) on the sonar output (Figure 9b). There was a tendency for the density of echoes to increase more rapidly at the No 1 and No 3 lights than at the center light (see Figure 10), suggesting movement of fish toward the lights was from both upstream and downstream directions.

Figure 10 and 11 present the digital output of tests run in a downstream and upstream direction. In both cases the rate at which the number of echoes increased at No 1 and No 3 lights was greater than at No 2 light. When each light was turned off the number of echoes dropped immediately. In the figures the number of echoes at each light when turned off did not reach the baseline indicating the extent of overlap between the depth ranges associated with each light.

In an upstream direction when the last light (No 1) was turned off the number of echoes at the downstream light (No 2) increased momentarily, indicative of the fish moving downstream when the last light was turned off. This occurred to a lesser extent at No 3 light when No 2 light was turned off which

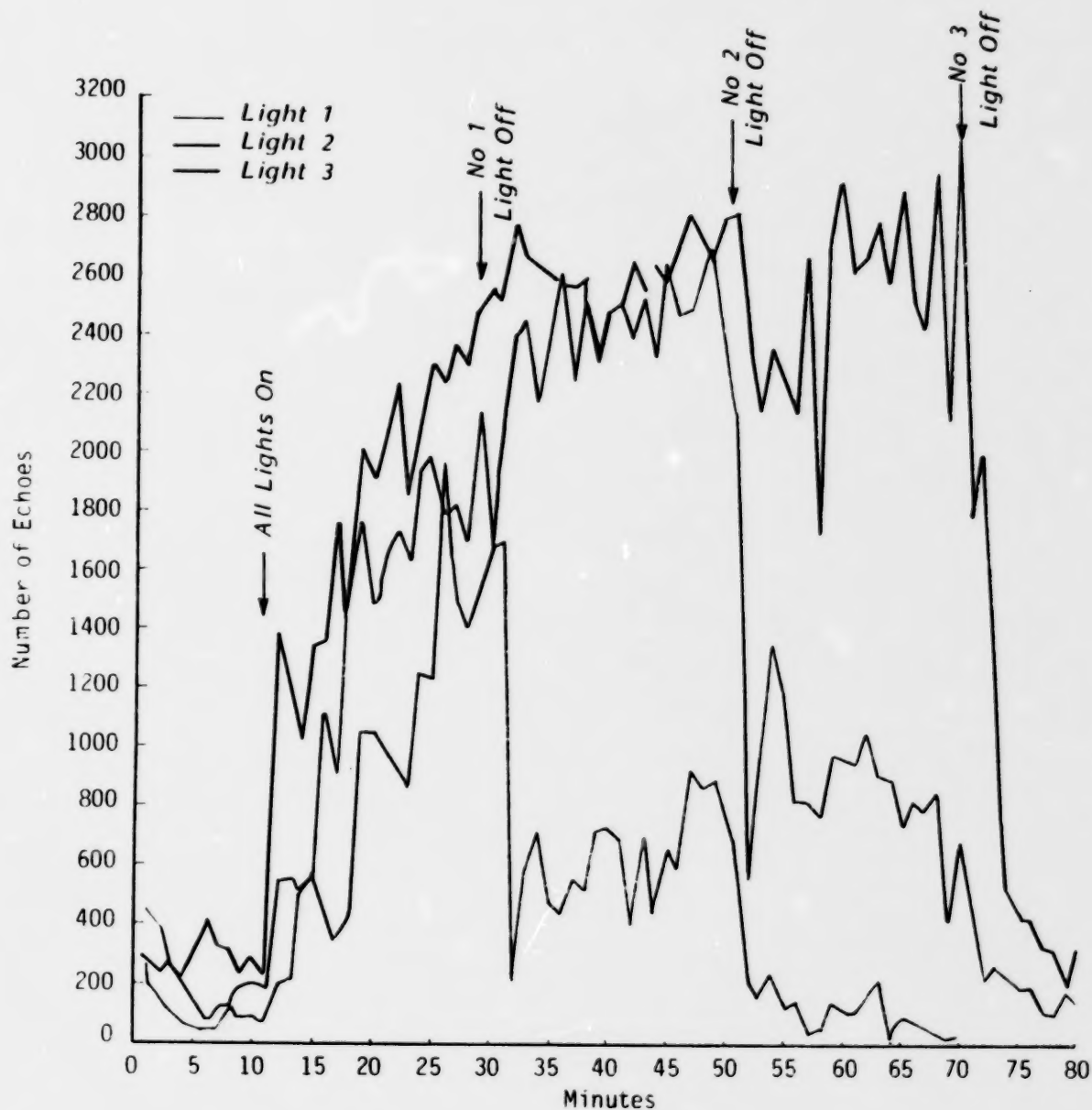


FIGURE 10
NUMBER OF ECHOES ASSOCIATED WITH LIGHT NO'S
1-3 WHEN THE LIGHTS WERE TURNED OFF
SEQUENTIALLY IN A DOWN STREAM DIRECTION

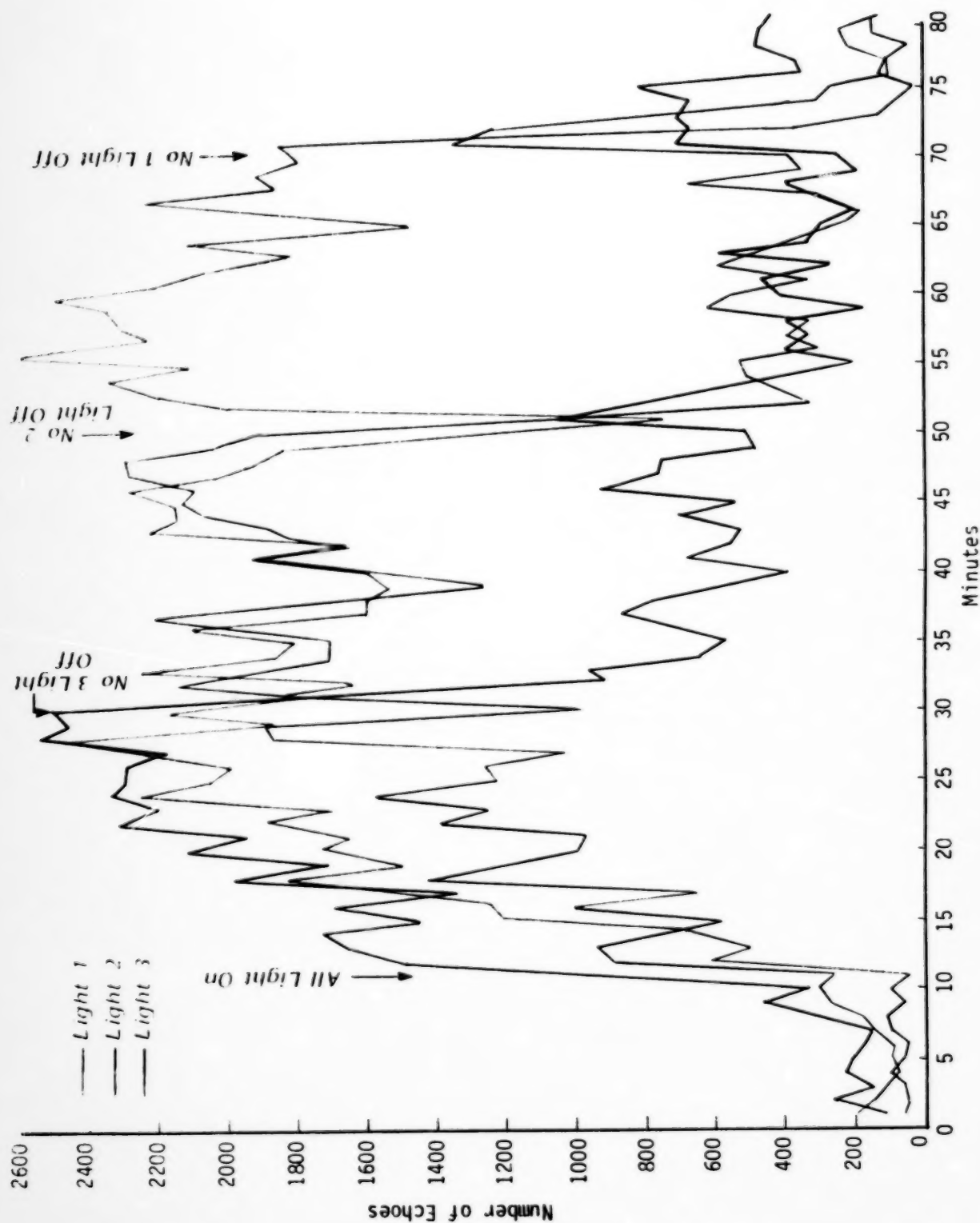


FIGURE 11
NUMBER OF ECHOES ASSOCIATED WITH LIGHT NOS 1-3 WHEN THE LIGHTS
WERE TURNED OFF SEQUENTIALLY IN AN UPSTREAM DIRECTION

substantiated the visicorder output which suggested that in both sets of experiments there was some downstream movement of fish when a light was turned off.

Tests Run While Tempering Pumps Were Operating

Tests of sequentially turning off lights were conducted when the tempering pumps were operating. Prior to the lights being turned on few or no fish were observable on the sonar output as in Figure 6b. When the lights were turned on, fish immediately appeared on the sonar output but quickly moved downstream, as illustrated by the diagonal lines on Figure 12, until the output was again similar to that of no lights on (Figure 6b). The current in the channel near the lights was in excess of 37 cm/s. Consequently, the results of this test suggest that when tempering pumps are operating fish are initially lured from their refuges by the lights but cannot or do not maintain their position in the current at the lights and actively or passively move downstream.

CONCLUSIONS AND RECOMMENDATIONS

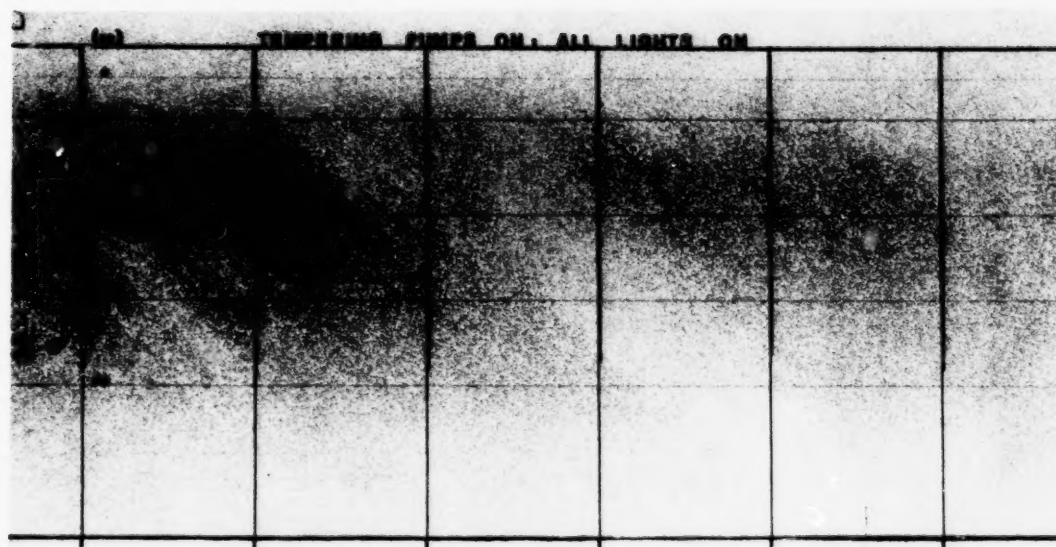
The results of this study indicate that mercury vapour lights are effective in attracting fish. The evidence also suggests that, when used in sequence, fish can be led downstream and, although it appeared that some fish were lost downstream, fish can be led upstream as well. It is not known whether those fish which moved downstream when the upstream tests were run were lost to the system or whether they eventually returned to the upstream light.

The two alternatives tested in this study, lights turned on and off in sequence, and lights turned off in sequence, appeared to work equally well. There also appeared to be no difference in fish response when the lights were separated by 11 m or 8 m.

As the apparent loss of fish downstream occurred when a light was turned off, it augurs well for the use of a sequential light system with an extractor which generates a current, such as a pump, as fish would likely move with the current into the pump when the final light was turned off.

An alternate setup which may prove more efficient in leading fish than the two tested in this study is the use of a single or series of lights which move along a track in the direction of an extractor. This would probably eliminate or reduce any downstream loss of fish before reaching the extractor due to extinguishing lights.

Distance From Transducer



Time →

FIGURE 12
PORTION OF SONAR OUTPUT FOR ALL LIGHTS
ON WITH TEMPERING PUMPS OPERATING

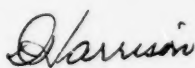
Finally, in a forebay situation, use of lights to lead fish will not work in relatively fast currents (37 cm/s). Consequently it is not recommended for a forebay where tempering pumps are employed.

ACKNOWLEDGEMENTS

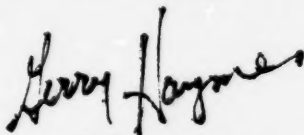
The contributions of Mr. L.P. King in design of the experimental setup and the collection of data is appreciated.

Approved:

Submitted:



D. Harrison
Manager
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G.T. Haymes
Unit Head -
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Biological Research Section

GTH:njm

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4. P.H. Patrick. 1981. "Response of Alewife to Mercury Vapour Light." Ontario Hydro Research Division Report No 80-413-K.

APPENDIX 1

NANTICOKE MERCURY VAPOUR GUIDANCE EXPERIMENTS

Date	Transect Number	Test Time	Test Description	Current Speed (cm/s)	H ₂ O Temp (°C)	Turbidity (NTU)	Light Measurement (Lux)
Nov 15/82	001	1855	Light #3 - 15 min off, 60 min on, 15 min off	6.5	7.0	4.3	
	002	2055	Light #2 - 15 min off, 60 min on, 15 min off	6.5	7.0	4.3	
	003	2230	Light #1 - 15 min off, 60 min on, 15 min off	6.5	7.0	4.3	
Nov 16/82	004	1900	Light #1 - 15 min off, 60 min on, 15 min off	6.5	7.0	6.2	
	005	2105	Light #2 - 15 min off, 60 min on, 15 min off	6.5	7.0	6.2	
	006	2225	Light #3 - 15 min off, 60 min on, 15 min off	6.5	7.0	6.2	
Nov 17/82	007	0005	Light #1 - 15 min off, 60 min on, 15 min off	6.5	7.0	6.2	
	008	2000	Light #2 - 15 min off, 60 min on, 15 min off	6.5	7.0	5.6	0.5 m east - 3.0 0.5 m west - 2.0 Centre -0 m - 1220 -0.5 m - 600 -1.5 m - 60 2.5 m - 22 3.5 m - 5.5 4.5 m - 2.0 5.5 m - 0.4 6.5 m - 0.1
	009	2255	Light #3 - 15 min off, 60 min on, 15 min off	6.5	7.0	5.6	

APPENDIX I (CONT'D)
NANTICOKE MERCURY VAPOUR GUIDANCE EXPERIMENTS

Date	Transect Number	Light Spacing (m)	Test Time	Test Description	Overlap Time (min)	Current Speed (cm/s)	Turbidity NTU	Water Temp (°C)
Nov 18/82	010	11	1945-1955 1955-2018 2015-2038 2035-2058 2055-2115 2115-2125	All off #2 on #1 on #2 on #1 on All off	3 3 3	6.5	4.5	11
Nov 22/82	011	11	2030-2040 2040-2103 2100-2123 2120-2143 2140-2203 2200-2223 2220-2243 2240-2300 2300-2310	All off #2 on #3 on #2 on #3 on #2 on #3 on #2 on All off	3 3 3 3 3 3 3	6.5	6.8	11.0
Nov 22-23/82	012	11	2345-0008 0005-0028 0025-0048 0045-0105 0105-0115	#1 on #2 on #1 on #2 on All off	3 3 3	6.5	6.8	11.0
Nov 23/82	013	8	2000-2010 2010-2033 2030-2053 2050-2113 2110-2133 2130-2155 2150-2215 2210-2235 2230-2250 2250-2300	All off #1 on #2 on #1 on #3 on #2 on #3 on #2 on #1 on All off	3 3 3 3 5 5 5	6.5	5.1	12.0
Nov 24/82	014	8	2355 0015 0035 0055-0105	All on #3 off #2 off All off				
	015	8	1905-1915 1920-1945 1940-2005 200-2025 2020-2045 2040-2100 2100-2110	All off #1 on #2 on #3 on #2 on #1 on All off	5 5 5 5	6.5	5.5	8.0
	016	8	2125 2145 2205 2205-2215	All on #3 off #2 off All off		6.5	5.5	8.0
		8	2245 2305 2325 2345-2355	All on #1 off #2 off All off		6.5	5.5	8.0

APPENDIX I (CONT'D)
NANTICOKE MERCURY VAPOUR GUIDANCE EXPERIMENTS

Date	Transect Number	Light Spacing (m)	Test Time	Test Description	Overlap Time (min)	Current Speed (cm/s)	Turbidity NTU	Water Temp (°C)
Nov 25/82	017	8	0005	All on		6.5	5.5	8.0
			0025	#3 off				
			0045	#2 off				
			0105-0115	All off				
	018	8	1925-1935	All off		6.5	13.5	8.0
			1945	All on				
			2005	#1 off				
			2025	#2 off				
			2045-2055	All off				
	019	8	2055	All on		6.5	13.5	8.0
			2115	#1 off				
			2135-2155	#2 off				
			2155-2220	#2 on	5			
			2215-2240	#1 on	5			
			2235-2300	#2 on	5			
			2255-2315	#3 on	5			
			2315-2325	All off				
Dec 2/82	020	8	1910-1920	All off		6.5	5.8	11.0
			1920	All on				
			1940	#3 off				
			2000	#2 off				
			2020-2030	All off				
	021	8	2040-2050	All off		6.5	5.8	11.0
			2050	All on				
			2110	#1 off				
			2130	#2 off				
			2150-2200	All off				
	022	8	2205-2215	All off		6.5	5.8	11.0
			2215-2240	#3 on				
			2235-2300	#2 on	5			
			2255-2315	#1 on	5			
			2315-2325	All off				
Dec 3/82	023	8	1825-1835	All off		Average 1-5 m profile 37.13	5.6	9.0
			1835	All on				
			1855	#1 off				
			1915	#2 off				
Dec 6/82	024	8	1935-1945	All off		37.13	7.8	10.0
			1835-1845	All off				
			1850	All on				
			1910	#1 off				
			1930	#2 off				
			1950-2000	All off				
	025	8	2000-2010	All off		37.13	7.8	10.0
			2010-2035	#1 on				
			2030-2055	#2 on	5			
			2050-2110	#3 on	5			
			2110-2120	All off				
	026	8	2135-2145	All off		37.13	7.8	10.0
			2145	All on				
			2205	#3 off				
			2225	#2 off				
			2245-2255	All off				

POOR

QUALITY

ORIGINAL